

1 LAND MOBILE SATELLITE—COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

5 1.FIELD OF THE INVENTION

This invention relates in general to a land mobile-satellite communication system and, in particular, to such a communication system which utilizes vehicles such as automobiles as carriers for newly introduced mobile repeater stations.

2. DISCUSSION OF RELEVANT ART

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20 Recently, several land mobile-satellite communication systems have been planed in which portable telephone terminals can communicate with each other through communication satellite stations mounted on each of a plurality of low earth satellites. In such land mobile-satellite communication systems, if both calling and called portable telephone terminals locate in the same service area provided by one communication satellite station, a communication link or speech path between both the calling and the called telephone terminals can be formed through the communication satellite station.

25 On the other hand, if the called telephone terminal is not located in the service area provided for the calling telephone terminal, a communication link between the calling and the called portable telephone terminals will be made through an inter-satellites communication link.

30 In the communication systems described above, the radio transmission paths formed between the portable telephone terminals and the low earth communication satellite stations are much shorter than that which may be formed between the portable telephone terminals and stationary satellite stations of high altitude above the equator. As a result, it is possible to

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1 form communication links of high quality between the portable
telephone terminals and the low earth communication satellite
stations without imposing excess antenna gain or excess
5 transmission power on either the communication satellites or
the portable telephone terminals. Such land mobile-satellite
communication systems are disclosed in USP 5,970,414;
6,072,768; 6,097,752; 6,108,561 etc..

10 However, to make such a communication system more
economical, it will be necessary to reduce the size of the low
earth communication satellite stations, including antennas,
and to reduce power consumption in both the communication
satellite stations and the portable telephone terminals.

15 Further, to make the communication more reliable and of
higher quality, it will be necessary to improve SN ratio in the
communication links between the portable telephone terminals
and the low earth communication satellite stations.

20 Moreover, it is necessary to provide various services to the
subscribers of such a land mobile-satellite communication
system which includes an accessibility to the conventional land
mobile communication systems and the conventional land net-
works such as Internet.

25 SUMMARY OF THE INVENTION

30 Accordingly, it is an object of the present invention to reduce
the size of the low earth communication satellite stations
including antennas.

It is another object of the present invention to reduce the
power consumption in both the low earth communication
satellite stations and the portable telephone terminals.

35 It is further another object of the present invention to
improve the reliability and the quality of the communication in
the land mobile-satellite communication system by increasing

1 SN ratio of the communication link between the portable
telephone terminals and the communication satellite stations.

5 It is still another object of the present invention to provide
various services to the subscribers of such a land mobile-satellite
communication system which includes accessibility to the
conventional land mobile communication systems and land net-
works such as the Internet.

10 These and other objects of the present invention are
achieved by the land mobile-satellite communication system of
the present invention comprising: at least one communication
satellite station, each said communication satellite station being
15 mounted on a corresponding low earth satellite; a plurality of
portable communication terminals for communicating with each
other through a communication link formed to include said at
least one communication satellite station; and a plurality of
mobile repeater stations mounted on mobiles located on the
20 earth for repeating a communication in said communication
link between said portable communication terminals and
including said at least one communication satellite.

25 According to a preferred embodiment of the present
invention, said repeater stations include a means for
communicating with said at least one communication satellite
station by using carrier waves of higher frequency than that of
carrier waves used for communicating with said portable
communication terminals.

30 According to another preferable embodiment of the present
invention, said portable communication terminals include a
means for transmitting a position signal repeatedly, said
position signal including an identification code of the portable
communication terminals and a test pattern; said mobile
35 repeater stations include a means for transmitting a repeated
position signal to said at least one communication satellite
station by adding a self identification code to said position

1 signal received from said portable communication terminals ;
and

5 said at least one communication satellite station includes a
means for selecting one of said mobile repeater stations which
transmits said repeated position signal including the test
pattern having a highest quality as a mobile repeater station
for the portable communication terminals.

10 According to another embodiment of the present invention,
said at least one communication satellite station includes a
means for working as Peering point or Proxies to provide
accessibility to the conventional land mobile telephone system or
Internet.

15 According to another preferred embodiment of the present
invention, each said low earth communication satellite station
includes a means for renewing cash by inter satellites
communication.

20 BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a schematic view showing a part of the land
mobile-satellite communication system according to an
embodiment of the present invention.

25 Fig. 2 is a block diagram showing an example of a
structure of the portable communication terminal P included
in the land mobile-satellite communication system shown in
Fig. 1.

30 Fig. 3 is a block diagram showing an example of a
structure of the mobile repeater station M included in the
land mobile-satellite communication system shown in Fig. 1.

35 Fig. 4 is a block diagram showing an example of a
structure of the communication satellite station mounted on

1 the low earth communication satelliteSi,Sj... included
in the land mobile-satellite communication system shown in
Fig. 1.

5 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

10 Fig. 1 is a schematic view of a part of the land mobile-
satellite communication system according to an embodiment
of the present invention. The system includes a plurality of
communication satellite stations each mounted on each
respective one of a plurality of low earth communication
satellitesSi , Sj..... Additionally the system includes a
15 plurality of mobile repeater stations M, a plurality of base
stations B and a plurality of portable communication
terminals P, although only one of each of these components is
shown, respectively, in Fig.1.

20 The portable communication terminals P may be carried
by persons such as pedestrians who communicate each other
through communication links which will be formed between
the portable communication terminals P to include one or
more low earth communication satellite(s)Si, Sj.... located
thereabove. The mobile repeater station M is mounted on the
25 mobile such as automobile V and has antenna AT to
communicate with both the satellites.... Si, Sj....above and the
portable communication terminals P .

30 Fig. 2 is a block diagram showing an example of a
construction of the portable communication terminal P. The
portable communication terminal P includes a CPU 11, a bus
12, a base band processor 13 for processing base band signals,
two transceivers 14a, 14b, a signal distributor 15, a hybrid
antenna 16 and an input/output part 17. One of the
35 transceivers 14a, 14b is used to communicate with the
communication satellite stations through the mobile

1 repeater stations M. The other of the transceivers 14a, 14b is
used to communicate with conventional mobile communication
systems such as PHP (Personal Handy Phone), etc.

5 The selection of the transceivers 14a, 14b is made
automatically according to a function selected by a subscriber
carrying this portable communication terminal P. The
selection of the hybrid antenna 16 corresponding to the
selected one of the transceivers 14a, 14b will be also made
10 automatically at the same time as the selection of the
transceivers is made.

Fig. 3 is a block diagram showing an example of a
structure of the mobile repeater station M. The mobile
repeater station M includes a CPU 21 which can also work
as a Server, a bus 22, a base-band processor 23, satellite
transceivers 24, a signal distributor 25, a high frequency
plane antenna 26, GHz band front-ends 27a-27d including a
frequency converter, a signal distributor 28, a multi-band
antenna 29 and a composite power supply 30. The base band
processor 23 includes a plurality of A/D converters and digital
signal processors (DSP) which operate at the same time.

25 The high frequency plane antenna 26 is fixed on the roof
of the vehicle such as an automobile as a part of the antenna
AT shown in Fig. 1 to be used for transmitting and receiving
signals with the low earth communication satellites Si,
Sj...above. The multi-band antenna 28 is embodied, for
example by a wide frequency band antenna such as a fractal
antenna to allow the mobile repeater station M to
communicate with various conventional communication
systems such as a land mobile system.

35 The communication with the low earth communication
satellite stations is performed by using high frequency band
such as Ku band which has been planed to be used for

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1 satellite caused by the use of the higher frequency band for
service links make it possible to reduce the size of the
communication satellites and, hence, makes it possible for
such a communication system to be constructed and
5 maintained with less cost.

The allocation of the higher frequency band for service
links, of course, causes a problem that transmission loss in
the service links will increase. However this problem can be
10 solved easily by introducing the mobile repeater stations to
be located between the low earth communication satellite
stations and the portable communication terminals P
according to the present invention.

15 The newly introduced mobile repeater stations make it
possible to compensate the increment of the transmission
loss in the service links by increasing antenna gain and
transmitting power of the mobile repeater stations. Since
the mobile repeater stations are mounted on the vehicle
20 from which a sufficient amount of electric power can be
easily supplied, it is possible to increase transmitting power
in the up service links or to use low noise receiver in the
down service links, which will consume a lot of power.

25 The composite power supply 30 in the mobile repeater
station M includes various types of power generators for
generating and storing electric power, such as a generator
which will be driven by a gasoline engine, or a fuel cell, or
solar batteries to assure enough power supply to the mobile
30 repeater station M.

The portable communication terminal P may be
carried by a subscriber such as a pedestrian or a car driver.
In the CPU 11 of the portable communication terminal P,
35 a position signal including the self identification code of the
portable communication terminal P and a predetermined

1 test pattern is read out from the data file inside the CPU 11
repeatedly. The read out of the position signal can be made
periodically or almost periodically in response to a trigger
signal from a timer inside or to some command from outside.
5 The read out position signal is transferred through the bus
12, the base band processor 13, the transceiver 14a and the
signal distributor 15 to be transmitted from the hybrid
antenna 16.

10 The position signal transmitted from the portable
communication terminal P may be received by the mobile
repeater station M located nearby. In the mobile repeater
station M, the received position signal may be transferred
from the multi-band antenna 29 to the CPU 21, through
15 the transceiver 27a, the base band processor 23 and the bus
22. The CPU 21 checks if the identification code of the
portable communication terminal included in the received
position signal has been already stored in the data file.

20 If it has not yet been stored in the data file, the CPU 21
stores the identification code included in the newly received
position signal after adding to it the current time. If the
position signal including the identification code has been
25 stored already in the data file, the CPU 21 just renews the
time to be added to it.

30 Further the CPU 21 makes a repeated position signal by
adding the identification code and the position of the mobile
repeater station itself to the received position signal. The
position of the mobile repeater station can be detected by using
various conventional methods, for example using a GPS
receiver. The CPU 21 transfers the repeated position signal to
the high frequency plane antenna 26 through the bus 22, the
base band processor 23, the satellite transceiver 24 and the
35 signal distributor 25 to be transmitted from the antenna 26
toward low earth communication satellite station(s) above.

1 The repeated position signal transmitted from the mobile
repeater station M will be received by the communication
satellite station mounted on the low earth communication
satellite Si locating above the mobile repeater station M. In the
5 satellite communication station, the CPU 41 will receive the
repeated position signal through the antenna 47, the beam
forming part 46, the signal distributor 45, the transceiver 44a,
the base band processor 43 and the bus 42. The CPU 41 makes a
registered repeated position signal by adding a current time to
10 the received repeated position signal and stores it in the data
file.

15 The CPU 41 may receive a plurality of repeated position
signals including the same identification code of the same
portable communication terminal P. In this case, the CPU 41
detects an error rate of the digits included in the test pattern for
each repeated position signal. The CPU 41 compares the digit
error rates detected from each of the registered repeated
position signals and gives priority to each of them according to
20 the lowness of the detected digit error rates e.g. the highness of
the quality of communication for the repeated position signals.
The CPU 41 thus may store a plurality of registered repeated
position signals of the same portable communication terminal P
which have been received from different mobile repeater
25 stations and have different priority.

30 A subscriber of the land mobile-satellite communication
system can call another subscriber's portable communication
terminal by putting a calling number into the subscriber's own
portable communication terminal. The calling number for
example can be the identification code of the portable
communication terminal to be called, which will be set by
inputting it from input /output part 17 of the calling
35 communication terminal. In the CPU 11 of the calling terminal,
a calling signal is made to include identification codes of both

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1 calling and called portable communication terminals and the
predetermined test pattern. The calling signal is transferred
through the bus 12, the base band processor 13, the transceiver
14 and the signal distributor 15 to the hybrid antenna 16 to be
5 transmitted.

The calling signal will be received by the mobile repeater
station M located in the vicinity of the calling portable
communication terminal P. In the mobile repeater station M,
10 the received calling signal will be transferred to the CPU 21
through the multi-band antenna 29, the transceiver 27a, the
base band processor 23 and the bus 22. The CPU 21 tries to
detect if the position signal has been stored in the data file
includes the same identification code as that of the called
15 portable communication terminal. If such a position signal has
been stored in the data file, the CPU 21 transmits a calling
signal for calling the called portable communication terminal.

If the CPU 21 receives a response from the called portable
communication terminal, the CPU 21 forms the communication
20 channel between both calling and called portable
communication terminals through the mobile repeater station M.
Thus the communication channel will be formed to be folded
back inside the mobile repeater station M to successively
25 connect the calling portable communication terminal — the
mobile repeater station — the called portable communication
terminal.

On the other hand, if the position signal including the
30 identification code of the called portable communication
terminal has not been stored in the data file, the CPU 21
makes a repeated calling signal for calling the called portable
communication terminal by adding the identification code and
the position of the mobile repeater station M. The CPU 21 then
35 transfers the repeated calling signal to the plane antenna 26
through the bus 22, the base band processor 23, the satellite

transceiver 24 and the signal distributor 25 to be transmitted toward the low earth satellite above.

The repeated calling signal transmitted from the mobile repeater station M will be received by a low earth communication satellite above. In the communication satellite station, the received repeated calling signal will be transferred from the antenna 47 to the CPU 41 through the beam forming part 46, the signal distributor 45, the transceiver 44a, the base band processor 43 and the bus 42. The CPU 41 tries to detect if the registered repeated position signal has been stored in the data file including the same identification code as that of the called portable communication terminal included in the received repeated calling signal.

If such a registered repeated position signal has been stored in the data file, the CPU 41 transmits a calling signal to the mobile repeater station having an identification code included in the registered repeated position signal for calling the called portable communication terminal. A plurality of the registered repeated position signals including the same identification code of the called portable communication terminal may be stored in the data file, as described above.

In this case, the CPU 41 selects one registered repeated position signal of the highest priority (of the highest communication quality) and transmits the calling signal to the mobile repeater station having the identification code included in the selected registered repeated position signal. Thus a call for the called portable communication terminal will be made through the selected mobile repeater station.

The calling signal transmitted from the low earth communication satellite station will be received by the selected mobile repeater station. In the selected mobile repeater station, the CPU 21 checks if the position signal including the

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1 identification code of the called portable communication
terminal has been stored in the data file. If it has been stored
in the data file, the CPU 21 transmits the repeated calling
signal for calling the called portable communication terminal.

5 If the CPU 21 receives a response signal from the called
portable communication terminal, the CPU 21 forms a
communication channel with the called portable communication
terminal. Thus, the communication channel is formed to connect
10 the calling portable communication terminal—the first mobile
repeater station—the low earth communication satellite station
— the second mobile repeater station — the called portable
communication terminal, successively.

15 On the other hand, if the registered repeated position
signal of the called portable communication terminal has not
been stored in the data file of the communication satellite
station, the CPU 41 in the communication satellite station
makes an inter-satellite calling signal by adding the
20 identification code of the communication satellite station to the
received repeated calling signal and transmits it to other
satellite(s) near by. Any other satellite which receives the inter-
satellite calling signal checks its data file to determine if the
registered repeated position signal including the identification
25 code of the called portable terminal is stored therein.

If it is stored in the data file, the CPU 41 in such other, or,
second, satellite makes a calling signal for calling the called
portable communication terminal through a corresponding
30 mobile repeater station. If the second satellite receives a
response from the called portable communication terminal
through the corresponding mobile repeater station, a
communication channel will be made between calling and called
portable communication terminals through inter-satellite
35 communication link.

1 On the other hand, if the registered repeated position
signal including the identification code of the called portable
communication terminal has not been stored in the data file in
the second satellite station which has received the inter-satellite
5 calling signal, the second satellite makes another inter-satellite
calling signal for calling the called portable communication
terminal by adding the identification code of the second
communication satellite station and transmits it to other
communication satellite(s) nearby.

10 The above said inter-satellite transmission of the calling
signal will be repeated until it reaches a communication satellite
station storing the registered repeated position signal of the
called portable communication terminal in its data file. As a
15 result, a communication channel or speech path will be made
between the calling and the called portable communication
terminals through a plurality of inter-satellite links.

20 In addition to the means for communicating with the other
portable communication terminals P through the mobile repeater
stations M and the low earth communication satellite stations as
described above, the portable terminal P further includes
additional means for communicating with other communication
systems including fixed radio base stations and public telephone
25 systems, such as PHS. As is shown in the block diagram of Fig. 2,
the portable communication terminal P includes the transceiver
14b in addition to the transceiver 14a and communicates with
conventional communication systems through the signal
distributor 15 and hybrid antenna 16.

30 As is shown in Fig. 3, the mobile repeater station M
includes various types of transceivers (Ghz frequency band
front-ends) 27b, 27c, 27d, each of which transmits and receives
carriers of different frequencies, and the base band processor 23,
35 in addition to the transceiver 27a so as to function as repeaters
between various communication terminals in other similar

1 communication systems and the other types of communication
satellites.

5 The base band processor 23 includes the A/D converters
and the plurality of DSPs (Digital Signal Processors) which
operate simultaneously in parallel. Various types of signals of
different frequency, modulation method or data format are
output from the transceivers 27b-27d and are converted fast by
the DSPs into common signals of the same frequency, the same
10 modulation method and the same data format to be processed by
the CPU 21.

15 Inversely, the common signals output from the CPU 21 are
converted fast into the various different types of signals and
transferred through the transceiver 27b-27d to be transmitted
from the multi-band antenna 29 toward the various
communication terminals excluding the portable communication
terminals P described above. Programs or softwares which run
in the DSP for processing the signals are replaced according to
the signals to be processed. Further, the programs for processing
20 the signals can be replaced by a method of down load if it is
necessary.

25 The high frequency plane antenna 26 is mounted on the
roof of the vehicle V and is implemented by an array antenna
composed of a plurality of plane antenna elements. The plane
antenna can tilt in a direction of a beam transmitted from it
from a direction of it's normal line in two dimensional directions
by controlling the phase of signals to be supplied to each of the
30 antenna elements in an appropriate manner. The angle of tilt of
beam measured from the nominal line of the plane antenna is
called a tilt angle of the plane antenna.

35 Further, the low earth communication satellites include a
means for detecting their positions from the information about
their orbits and current time and a means for informing their

1 detected positions to the mobile repeater stations through down
links. The mobile stations include a means for tracking the low
earth communication satellites by controlling the tilt angles of
their plane antennas in response to the positions of the low
5 earth communication satellites and their positions detected by
using the GPS receivers, etc.

The low earth communication satellite stations preferably
include a means for scanning their antenna beams to the mobile
10 repeater stations by controlling the beam forming part 46 in
response to their own positions and the mobile repeater stations
included in the received repeated position signals.

As described above, in the case in which there are a plurality
15 of the mobile repeater stations around the portable
communication terminal, a plurality of the communication
channels can be formed between the portable communication
terminal and the communication satellite above through
different mobile repeater stations near by. In this case, only
20 one communication channel of the highest communication
quality (of the lowest digit error rate of the test pattern in the
registered repeated position signal) is selected as a present
communication channel or link and the other communication
channels or links are reserved as spares, as described above.

25 If the order of the quality of communication channels
changes between the present and the spare communication
channels, the communication channel itself will be switched
between both the present and the spare communication
30 channels to result in the replacement of the mobile repeater
stations between the portable repeater stations and low earth
communication satellite stations .

35 If the switching of the communication channels described
above is made frequently, an efficiency of the communication
will be lowered. To avoid such an undesirable situation, a

1 tracking between the low earth communication satellites and
the mobile repeater stations will be performed by scanning their
antenna beams so as to keep the quality of the communication of
the present communication channel maximum. The tracking
5 performed by scanning antenna beams is an effective way to
keep efficiency of communication to be high value , especially
when a large amount of data is being transferred between the
mobile repeater stations and the low earth communication
satellite stations.

10 The land mobile — satellite communication system of the
present embodiment is constructed to allow transmission and
reception of massive data with other land net-work data
communication systems, such as Internet. When each of the low
15 earth communication satellite stations reaches above each of the
base stations B which also work as nodes for transmitting and
receiving data with the other or conventional land network
systems, the communication satellite station transmits a
request to the base station B for sending data stored in the
20 other net-works, for example the Servers in the Internet, to the
low earth communication satellite station.

25 The base station B which has received the request from the
communication satellite station transmits the data requested. In
the satellite station which receives the data sent from the base
station B, the received data will be stored in the data file in the
CPU 41 which also works as a server in the land mobile-satellite
communication system of the present embodiment. In this way,
30 the communication satellite stations also include the Server and
Peering point function for transmitting and receiving data
between different net-works such as Internet.

35 When the communication satellite station receives a
request for transmitting data from the portable communication
terminals P through the mobile repeater stations M, the CPU 41
in the communication satellite station checks if the requested

1 data has been stored in the data file. If the data has been
stored in the data file, the CPU 41 reads out the data from the
data file and transmits it to the portable communication
terminals P which has sent the request through the mobile
5 repeater stations M. If the requested data has not been
stored in the data file, the CPU 41 transmits a request to other
communication satellite(s) through inter-satellite links for
sending the data to it.

10 When the communication satellite station receives the
requested data transmitted from another communication
satellite station, the data will be stored in the data file in the
CPU 41. The CPU 41 then transmits the data under request to
the mobile repeater station M which has repeated or relayed the
15 request for the data from the portable communication terminals
P.

20 The mobile repeater station M which received the
data will store it in the data file and will transmit it to the
portable communication terminal which issued the request.
Thus, the data requested by any one of the portable
communication terminals P will be stored in the data file in the
mobile repeater station M which transferred the data in
response to the request. When a new request for sending the
25 newly stored same data is issued by another portable
communication terminal P, the newly stored data will be read
out from the data file in the mobile repeater station M and will
be transmitted to the other portable communication station P.

30 Thus, the mobile repeater station M include a functions of
Cashing, Proxy and Server for storing transferred data inside
the mobile repeater station as a cash, and for transmitting the
cash to other portable communication terminals which issue
requests for the same data.

35 The mobile repeater station M transmits a request for

1 increasing the beam width, a subscriber carrying the portable
communication terminals P can report some special traffic
information he has found, for example appearance of an
5 obstacle caused by a natural disaster such as a landslide to the
other portable communication terminals P dispersing nearby
through the mobile repeater stations M and the communication
satellite station.

10 The mobile repeater stations M include a means for
collecting and storing or transmitting to the satellite stations
information about traffic or environment of the surrounding
region for example, images taken by camera mounted on the
vehicle, the climate data such as temperature or humidity, a
15 situation of a traffic jam which may be measured, for example by
a mean cruising velocity of the vehicle itself. This information is
stored in the data files inside the communication satellite
stations. The subscribers of the land mobile-satellite
communication system of the present embodiment carrying the
20 portable communication terminals P can obtain the information
about traffic and environment in the various remote regions
obtained by the mobile repeater stations M locating in each
regions.

25 The mobile repeater station M and the accompanying
antenna can be mounted on a car which belongs to or is leased
by a person who contracted with a manager of the land mobile-
satellite communication system of the present invention. As a
mobile for carrying the mobile repeater stations, ships such as
30 motor boats can be used instead of vehicles.

Although the invention has been described above with
reference to only a limited number of presently preferred
embodiments, the embodiments are not intended to limit the
scope of the invention. Many modifications and variations are
35 possible within the scope of the invention, as indicated appended
claims.

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